Using Remote Sensing to Support Water Resource Management under Drought Conditions

Introduction

Water management has become increasingly complex as floods and droughts intensify worldwide. Earth Observation (EO) technologies now play a vital role in monitoring and managing water resources. Applications include land use and flood mapping, drought assessment, snow and wetland monitoring, and water quality evaluation. Multispectral sensors such as Landsat-8, Sentinel-2, and SPOT provide critical data for these analyses. The GRACE mission, combined with platforms like TRMM and MODIS, enables estimation of total water storage, groundwater levels, and surface water balance. Integrating satellite and ground observations improves understanding of hydrological changes and drought impacts. EO-based water management contributes directly to achieving Sustainable Development Goals (SDGs), particularly clean water and sanitation (SDG 6), zero hunger (SDG 2), and poverty reduction (SDG 1). The growing availability of EO data offers significant opportunities to strengthen resilience and promote sustainable water management worldwide.

Resolution

Resolution in remote sensing is multi-dimensional, encompassing spatial, spectral, radiometric, and temporal aspects, all of which determine data suitability for water resource studies. Data can be acquired from ground-based sensors, airborne platforms (e.g., drones), or spaceborne satellites. While satellite data typically offer broader coverage, their spatial resolution is lower than airborne sensors, necessitating a trade-off between detail and area coverage. Small-scale studies, such as local water quality monitoring, wetland assessment, or urban stormwater analysis, often require moderate-resolution datasets capable of detecting subtle variations in water optical properties. Effective water quality assessment relies not only on spatial resolution but also on sufficient spectral and radiometric sensitivity to capture features like chlorophyll concentration or turbidity. Multi-spectral sensors such as MODIS, with moderate spatial coverage but high spectral precision, exemplify this balance. Selecting datasets that optimally integrate spatial, spectral, and radiometric resolution is essential to accurately monitor hydrological dynamics and support informed water management decisions.

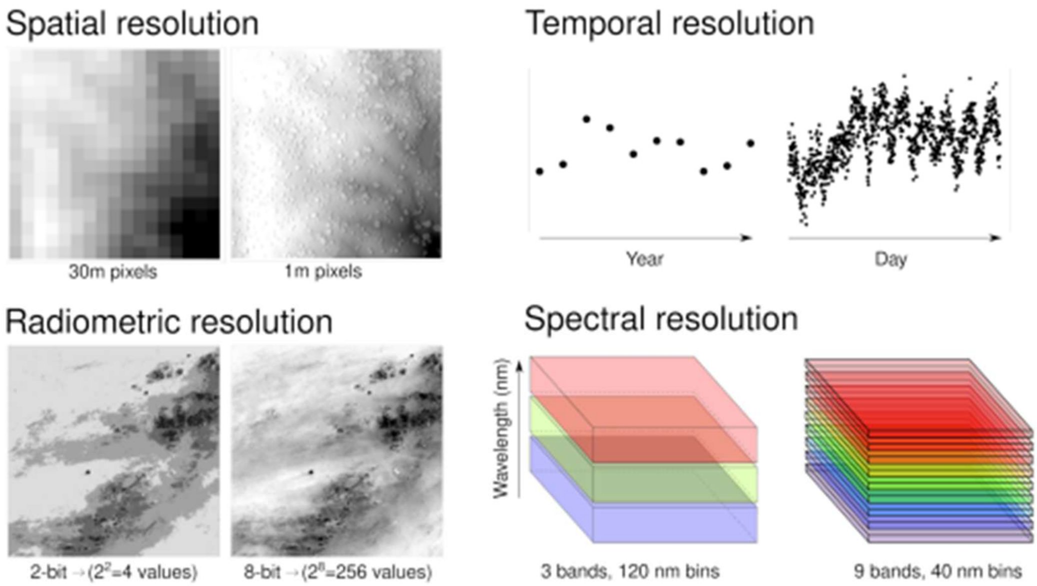

Figure 1: Comparison of Different Resolutions (Source: Mahood et al., 2023)

Remote sensing applications in water resource management

Remote sensing technologies have become vital tools in modern water resource management, enabling large-scale and continuous observation of environmental dynamics. They provide essential data that support informed and timely decision-making in response to increasing environmental pressures. As climate change intensifies events such as droughts and floods, integrating remote sensing into water management is crucial for sustainable planning and risk reduction. By utilizing Earth Observation (EO) data from multiple satellite platforms, these technologies facilitate monitoring of key hydrological components including precipitation patterns, water quality, and ecosystem changes. This integration strengthens the capacity to anticipate drought conditions, manage water scarcity, and enhance resilience in the face of growing climatic variability. For a comprehensive list of satellite instruments and their specific measurements (such as liquid water and precipitation rate), the CEOS MIM Database (Overview of Measurements Made by Earth Observation Satellites) can be consulted (https://database.eohandbook.com/measurements/overview.aspx).

Monitoring the hydrological cycle is crucial for effective water resource management. Precipitation, a key component, governs the movement and balance of water among rivers, lakes, and aquifers. While seasonal variations are normal, anomalies in rainfall intensity or distribution can signal disruptions, including droughts or floods, that affect water availability and quality. Excessive rainfall may increase runoff, transporting pollutants and nutrients that degrade aquatic ecosystems, while rising sea levels can cause saltwater intrusion into freshwater supplies. Earth Observation (EO) data provides timely, large-scale monitoring of these dynamics, enabling early detection of anomalies and informed interventions to safeguard water resources and ecosystems.

Accurate rainfall measurement from space relies on both single-sensor and multi-satellite products, primarily using radar and microwave radiometers. Each sensor type has limitations in coverage and accuracy, which can be addressed through multi-sensor integration. Microwave sensors detect precipitation by measuring energy emitted or scattered by raindrops, but have low temporal resolution. Integrating these with infrared data from geostationary satellites offering frequent coverage, enhances monitoring. Combining radar and satellite data further improves measurement, with radar providing detailed intensity and structure information, and satellites offering broad spatial coverage. Advanced algorithms, such as the IMERG algorithm used in the Global Precipitation Measurement (GPM) mission, merge data from multiple sensors to produce accurate, near real-time global precipitation estimates. Multi-sensor approaches allow cross-validation, error correction, and fill temporal and spatial gaps, crucial for monitoring extreme events. These integrated datasets support water resource management, drought and flood monitoring, agricultural planning, climate research, and weather forecasting, improving understanding of the global hydrological cycle.

Table: Satellite missions for observing precipitation

Mission	**Launch date/product period**	**Spatial Resolution**	**Temporal Resolution**	**Sensor**	**Wavelength**	**Link to Data product**
TMPA	2000–2018	0.25º	3-hourly	TRMM Microwave Imager	Microwave frequencies	https://gpm.nasa.gov/data/directory
PERSIANN	2000 – present	0.25º	1-hourly	CCD Scanner	Infrared spectrum	http://chrsdata.eng.uci.edu/
MSWEP	1979 – present	0.1º	3-hourly	Integrates multiple satellite and gauge data	Varies	http://www.gloh2o.org/
CHIRPS	1979 – present	0.05°	6-hourly to 3-monthly	Various satellite and ground-based sources	Infrared, visible, near-infrared	http://chg.geog. ucsb.edu/data/chirps/
GPM/IMERG	2015 – present	0.1°60° S to 60°N	30 minutes	Dual-frequency Precipitation Radar),	Multiple frequencies	https://pmm.nasa.gov/data-

				GPM Microwave Imager (GMI)		access/downloads/gpm
AMSR2 (GCOM-W1)	2012–present	~10–25 km	~1–2 passes/day	Advanced Microwave Scanning Radiometer 2	Microwave	https://www.earthdata.nasa.gov/data/instruments/amsr2
SSMIS (DMSP)	1987–present	~25 km	~1–2 passes/day	Special Sensor Microwave Imager/Sounder	Microwave	https://www.ncei.noaa.gov/data/ssmis-brightness-temperature-rss/access/
CloudSat	2006–2023	~1 km (vertical)	~1–2 passes/day	Cloud Profiling Radar	Ka-band radar	https://www.cloudsat.cira.colostate.edu/
MetOp-B/C	2012–present	~16 km	~1–2 passes/day	Advanced Microwave Sounding Unit (AMSU)	Microwave	https://www.eumetsat.int/our-satellites/metop-series